

WHAT ARE RADIATION-INDUCED SIDE EFFECTS?

Radiation-based experiments help us understand and preserve heritage. However, depending on the level of exposure, irradiation may lead to undesirable side effects that can be:

Visual	such as discolouration or colouration
Chemical	such as change in oxidation state
Mechanical	such as embrittlement

These effects can happen instantaneously or over a longer period of time, and in some cases may become apparent after a certain conservation treatment (e.g., wetting).

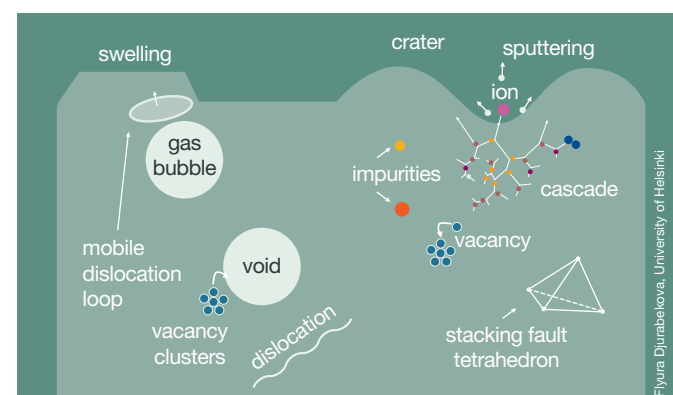
Avoiding such effects is extremely important when dealing with unique and valuable heritage objects.

Although analytical results are based on particle-matter interactions, they may also lead to undesired:

Primary effects (such as knock-out atoms, vacancies, radicals, broken bonds, cross-linking)

Secondary effects (such as oxidation of compounds at the sample surface as a result of the formation of ozone)

Heritage objects can be heterogeneous and complex, and may contain unexpected materials.



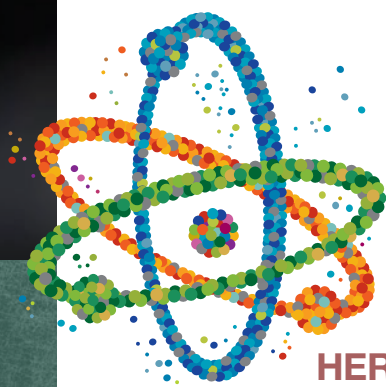
Overview of the various defects that can occur as a result of particle-matter interactions



STUDY AND REPORT

Sharing experience and knowledge is important for ensuring safe analysis of heritage objects and materials. Documentation, data preservation and publications on the effects of experiments on heritage materials are crucial.

Photograph: © Christophe HARGOUES / C2RMIF / AGLAE / CNRS Photothèque



ACCELERATORS
FOR HERITAGE

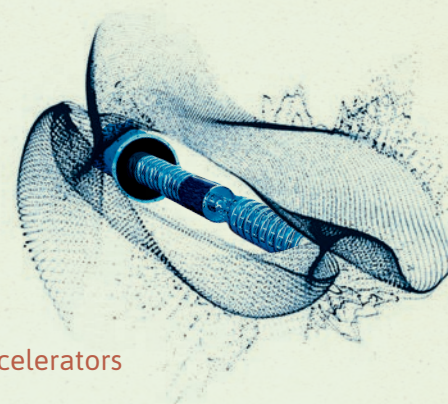
**SAFE
ANALYSIS
OF CULTURAL
AND NATURAL
HERITAGE OBJECTS
AND MATERIALS**

Developing good practice for minimizing
radiation-induced side effects



Accelerator Knowledge Portal

nucleus.iaea.org/sites/accelerators



Find more on the IAEA Accelerator Knowledge Portal

19-00382E



IAEA

International Atomic Energy Agency
Atoms for Peace and Development

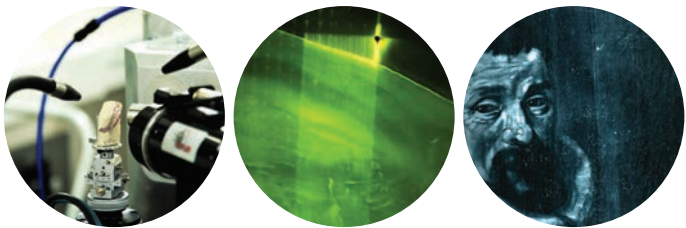
ALARA

As Low As Reasonably Achievable

The ALARA radiation safety principle is based on minimizing exposure to radiation by employing all reasonable means.

For heritage objects, we can consider:

Time	Reduce the time of exposure. Minimize analysis time as much as possible. Optimize the detection parameters.
Intensity	Use the minimum dose/fluence and flux required to obtain the information desired from the experiment.
Shielding	Avoid unnecessary beam exposure.
Environment	Control environment and atmosphere (e.g. inert gas, vacuum, low temperature, humidity, light).



MONITORING

Monitor the material composition in tandem with the radiation experiment itself using non-destructive measurements.

Monitor the probed data itself in real time to track any noticeable change.

If any effect is noticed, the experiment should be stopped before further damage occurs.

BEFORE THE EXPERIMENT

In preparing an experiment using irradiation, such as:

- particle beams
- laser beams
- neutron beams
- X-rays or gamma rays

These powerful tools help to better understand the production, history, interpretation, meaning, diagnosis and preservation of objects in cultural and natural history collections.

Radiation-induced side effects may affect your results or the investigated material.



Identify and document the composition, history and current condition of the sample or object.

Decide on the analytical sequence, taking into account the effects of different techniques on the chemical composition and physical state of the sample or object.

Predefine the region of interest where analysis will be performed.

Decide on methods to monitor the state of the sample or object during and after the irradiation experiment.

DID YOU KNOW?

Experimental doses are measured in grays. One gray corresponds to an energy of one joule absorbed per kilogram of matter. Integrated surface doses can reach the gigagray level for experiments under intense radiation.

DURING THE EXPERIMENT

Carefully check and record:

1. Probing-beam parameters
 - Wavelength / Energy Power / Fluence
 - Working distance / Sample contact
 - Deposited dose
2. Sample parameters
 - Absorption properties of materials
3. Environmental parameters
 - Sample preparation (subsampling, embedding media, etc.)
 - Measurement environment (atmosphere, temperature, humidity, etc.)

AFTER THE EXPERIMENT

Immediate Characterization

Characterization of the sample after the experiment should be done in the same manner as pre-experiment characterization.

Long Term Effects

Changes in the sample properties may develop over long periods of time. Follow-up characterizations should be performed at regular intervals to examine these effects.

